09-21-00 A

PATENT

Docket No. IL-10623

Commissioner for Patents
Washington, DC 20231

NEW APPLICATION TRANSMITTAL

Transmitted herewith for filing is the patent application of Inventor(s):
Christine A. Smith and Howard W. H. Lee

For (title): **MATERIAL SYSTEM FOR TAILORABLE WHITE LIGHT EMISSION AND METHOD FOR MAKING THEREOF**

1. **Type of Application**
   - ■ This new application is for an original patent.
   - ☐ This new application is a:
     - ☐ Division
     - ☐ Continuation
     - ☐ Continuation-in-part (CIP)

2. **Benefit of Prior U.S. Application(s) (35 USC 120)**
   - ☐ The new application being transmitted claims the benefit of prior U.S. application(s).
     - ☐ Group/Art Unit:
     - ☐ Examiner of Prior Application:

3. ☐ **Benefit under 35 U.S.C. 119(e) of United States provisional application(s) listed below:**

Application Serial No. Filing Date

4. **Papers enclosed which are required for filing Date Under 37 CFR 1.53(b).**
   - 26 Pages of specification, including Claims, Abstract and Title Page
   - 10 Sheets of formal drawings

5. **Additional papers enclosed**
   - ☐ Preliminary Amendment
   - ■ Express Mail Certificate
   - ■ Return Postcard

6. **Declaration or oath**

- ■ Enclosed and executed by
  - ■ Inventors
  - ☐ legal representative of inventor(s) 37 CFR 1.42 or 1.43
- ☐ Not Enclosed

7. **Assignment**

- ■ An assignment of the invention to The Regents of the University of California.
  - ■ is attached
  - ☐ will follow

8. **Certified Copy**

Certified copy(ies) of application(s)

(country)	(application no.)	(filed)
(country)	(application no.)	(filed)

from which priority is claimed

- ☐ is(are) attached.
- ☐ will follow

9. **Fee Calculation**

CLAIMS AS FILED								
Type of Claim	Number Filed		Included in Basic Fee		Number Extra	Rate		Total Fee
Total Claims	53	-	20	=	33	x $18	= $	594.00
Independent Claims	18	-	3	=	15	x $78	= $	1,170.00
						Multiple Claims	= $	1,764.00
						Basic Filing Fee	= $	690.00
						Sub-Total	= $	2,454.00
						Small Entity Filing Fee	= $	1,227.00

10. **Small Entity Statement(s)**

- ■ Verified Statement that this is a filing by small entity under 37 CFR 1.9 and 1.27 is attached.
- ☐ Copy of Verified Statement that this is a filing by small entity under 37 CFR 1.9 and 1.27 filed in prior application. Status still proper and desired.

11. **Fee Payment**

- ☐ Not Enclosed
- ■ Enclosed (See Charge Account Information Below)

Total Basic Filing Fees To Be Paid $ 1,227.00

12. **Method of Payment of Fees**

- ☐ Check in the Amount of $ _____
- ■ Charge Account No. 12-0695 in the amount of $ 1,227.00

A duplicate of this transmittal is attached.

13. **Instructions As To Overpayment/Underpayment**

- ■ credit/charge
  Account No. 12-0695
- ☐ refund

14. **Correspondence Address**

Christopher J. Horgan
Patent Attorney
P.O. Box 808, L-703, Livermore, CA 94551
USA

Tel: (925) 423-8554
Fax: (925) 423-2231

Reg No.: 40,394

Christopher J. Horgan
ATTORNEY
P.O. Box 808, L-703
Livermore, CA 94551

Date: 9/19/00

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : Christine A. Smith et al. Attorney Docket No. : IL-10623

Serial No. : Art Unit:

Filed : Examiner:

For : Material System for Tailorable White Light Emission And Method For Making Thereof

Commissioner for Patents
Washington, D.C. 20231

EXPRESS MAIL CERTIFICATE

"Express Mail" label number EL533020001US

Date of Deposit 9/19/00

I hereby certify that the following *attached*

1. Recordation Cover Sheet w/Assignment
2. New Application Transmittal (in duplicate)
3. Verified Statement Claiming Small Entity Status
4. Application
   (Specification w/title page 16 pages, Claims 9 pages, Abstract 1 page)
   Combined Declaration and Power of Attorney
   Ten (10) sheets of formal drawings;
5. Express Mail Certificate
6. Return postcard

is being deposited with the United States Postal Service "Express Mail Post Office to addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to Commissioner for Patents, Box: Patent Application, Washington, D.C. 20231.

Kathy E. Raymond
(Type or print name of person mailing paper)

Kathy E. Raymond
(Signature of person mailing paper or fee)

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant	: Christine A. Smith et al.	Docket No.	: IL-10623
Serial No.	:	Art Unit	:
Filed	:	Batch No.	:
For	: Material System For Tailorable White Light Emission And Method For Making Thereof	Examiner	:

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS [37 CFR 1.9 (f) and 1.27(d)] - NONPROFIT ORGANIZATION

I hereby declare that I am an official empowered to act on behalf of the nonprofit organization identified below:

The Regents of the University of California
Office of General Counsel
1111 Franklin Street
Oakland, CA 94607-5200

TYPE OF ORGANIZATION

__X__ University or other Institute of Higher Education

I hereby declare that the nonprofit organization identified above qualifies as a nonprofit organization as defined in 37 CFR 1.9(e) for purposes of paying reduced fees under Section 41(a) and (b) of Title 35, United States Code with regard to the invention: **Material System For Tailorable White Light Emission And Method For Making Thereof**
by inventor(s) **Christine A. Smith and Howard W. M. Lee**

described in

__X__ the specification filed herewith.

_____ application serial no._____, filed_____.

_____ patent no. _____, issued _____.

I hereby declare that rights under contract or law have been conveyed to and remain with the nonprofit organization with regard to the above identified invention, except for a license to a Federal Agency pursuant to 35 USC 202(c) (4).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

_X_ no such person, concern, or organization

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true: and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

JANET G. TULK
Laboratory Counsel
Lawrence Livermore National Laboratory
7000 East Avenue, L-701
Livermore, CA 94551

Janet G Tulk — 9-13-00

JANET G. TULK — Date

S-94,209

IL- 10321

MATERIAL SYSTEM FOR TAILORABLE WHITE LIGHT EMISSION AND METHOD FOR MAKING THEREOF

BY

Christine A. Smith (USA)
1264 Blossom Circle
Livermore, CA 94550

Howard W. H. Lee (USA)
45176 Imnaha Court
Fremont, CA 94539

MATERIAL SYSTEM FOR TAILORABLE WHITE LIGHT EMISSION AND METHOD FOR MAKING THEREOF

The United States Government has rights in this invention pursuant to Contract No. W-7405-ENG-48 between the United States Department of Energy and the University of California for the operation of Lawrence Livermore National Laboratory.

FIELD OF THE INVENTION

The present invention relates generally to materials suitable for emitting electromagnetic radiation when suitably excited, and more specifically, further relates to tailoring such emissions by the materials.

BACKGROUND OF THE INVENTION

In the flat panel display field, liquid crystal displays (LCDs) are one of the preeminent display technologies and will continue to play a major role in flat panel displays. An important component of LCDs is the white light emitter that comprises the back light for the display since liquid crystals (LCs) do not generate light – they may only block it. Typically, LCDs allow 5-25% of the back light to pass through. As a result, LCD technology requires a significant amount of energy, and this is an important consideration in lightweight laptop or other display designs. An efficient and spectrally broad white light source would constitute an important contribution to LCD technology.

SUMMARY OF THE INVENTION

Aspects of the invention include a method comprising: directing an energy beam at a pre-processed composite material having a matrix containing a plurality of nanocrystals and a plurality of traps to reduce the size of said plurality of nanocrystals and the number of the plurality of traps to produce a post-processed composite material.

Aspects of the invention further include a method of tailoring white light emission from a composite having optical properties using zinc selenide (ZnSe) nanocrystals comprising: fabricating the ZnSe nanocrystals; incorporating the ZnSe nanocrystals into the matrix; and tuning the optical properties of the composite to a predetermined application.

Aspects of the invention further include a material system comprising: a plurality of nanocrystals; a plurality of first and second traps; and said plurality of nanocrystals, first traps and second traps capable of emitting white light in combination when excited.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated into and form a part of the disclosure,

Figure 1A shows a composite material before the processing steps disclosed herein;

Figure 1B illustrates a light emission spectrum of the pre-processed composite material of Figure 1A on a linear scale;

Figure 2 shows the composite material of Figure 1A being irradiated; and

Figure 3A shows a post-processed composite material after the irradiation process;

Figure 3B illustrates a light emission spectrum of the post-processed composite material of Figure 3A on a linear scale;

Figure 4 illustrates a flow diagram of an iterative processing method of the present disclosure;

Figure 5 discloses a white light source for general lighting applications using the post-process composite material;

Figure 6 illustrates a liquid crystal display (LCD) using the post-process composite material as the white emitting back light;

Figure 7 illustrates a light emitting diode (LED) using the post-process composite material having a various colors; and

Figure 8 illustrates a pixel of a full color electroluminescent display composed of a plurality of sub-pixels each including a post-processed composite.

DETAILED DESCRIPTION

Typically white light emitting devices do so through contributions of several spectral components, usually red, green and blue color light. Nanocrystals embedded in a matrix to form a composite material may be used in these light emitting devices. Nanocrystals are defined as single crystal particles having average dimensions approximately in the range of 1 to 20 nanometers (nm), and typically approximately 2 to 6 nm, but whose dimensions are ultimately determined by the nanocrystal material and dimensions required to effect quantum confinement. Quantum confinement is the shifting of energy levels to higher energies as the particle size decreases. Due to their small size, nanocrystals confine carriers (electrons and holes) three-dimensionally so that the effect of the quantum confinement of carriers may be obtained. The use of the terms "hole" and "holes" herein is intended to refer to vacant electron energy states, typically near the top of an energy band, in a solid. Quantum confinement causes the energy of the light emitted to increase as the size of the nanocrystal decreases, or equivalently, quantum confinement causes the wavelength of the light emitted to decrease as the size of the nanocrystal decreases. The exact size of the nanocrystals is dictated by the color of light to be generated. Blue light, for example, requires smaller nanocrystals than red light. A composite containing the nanocrystals may then be energized by several

different types of energy sources (e.g., a light source, electrical current, or electron beam) so that fluorescence may be induced.

Figure 1A illustrates a pre-processed composite material 10 containing nanocrystals 14 in a matrix material 12 in a first state before the processing steps described herein. The height, h, of the pre-processed composite material may range from approximately 1 to 10 millimeters (mm), the width, w, of the pre-processed composite material may range from approximately 1 to 10 mm, and the depth, d, may also range from approximately 1 to 10 mm. The matrix material 12 may be a potassium borosilicate glass matrix. However, other matrix materials may also be used that allow the incorporation of nanocrystals and which give rise to impurities or traps 16 and 18. Reference numerals 16 and 18 are used herein to indicate that there are at least two types of traps in the matrix material 12 that emit in the visible light range as will be described below. Reference numeral 16 indicates "red" traps that emit light in the red region and reference numeral 18 indicates "green" traps that emit light in the green region. Traps 16 and 18, as used herein, are defined as any species such as impurities or defects that are not the nanocrystals (though they may be contained within the nanocrystals) and which may either be excited by an energy source to produce light emission or may trap excited carriers (electrons or holes) from the nanocrystals to produce light emission.

The pre-processed composite material 10 of Figure 1A is constructed in the following manner. ZnSe nanocrystals 14 in a potassium borosilicate glass

matrix 12 are prepared by first melting a base glass composition formulated specifically for compatibility with Group II-VI semiconductors. The base glass consists of (in weight (wt) %): 56% silica, 24% potassium oxide, 9% barium oxide, 8% boron oxide, and 3% calcium oxide. Twenty-five to thirty gram batches of this oxide powder mixture are melted in alumina crucibles and refined to remove bubbles at 1400°C for several hours. Following melt casting, the glasses are ground into a fine powder. Next, ZnSe powder is added and the blended mixture is re-melted again at 1400°C for approximately one and a half hours before casting the melt into small slabs. Excess ZnSe is added to compensate for the expected volatilization losses from the melting process. As-cast samples may appear reddish orange after overnight annealing at approximately 350°C. High-resolution transmission electron microscopy (HRTEM) on these samples should show crystalline ZnSe particles with varying nanometer sizes. Typical sizes obtained are 5.5 ± 1.7 nm. These as-cast samples may then be successively cycled through re-melting and rapid quenching. HRTEM should show an average diameter particle size for quenched crystalline ZnSe particles of 3.7±1.1 nm. As discussed above, in addition to the ZnSe nanocrystals 14 in the matrix material 12, the pre-processed composite 10 also contains at least two types of traps 16 and 18.

The method and device of the disclosed embodiments are concerned with controlling the properties of the nanocrystals and the traps of the pre-processed composite 10 to tailor the blue, red and green contents of the light

emission of the pre-processed composite material 10 to control the white light emission of post-processed composite material (reference numeral 30 in Figure 3A). The white light emission of the post-processed composite material 30 will be tailored (or tuned) by controlling each of the contributions of the blue, red and green components a predetermined level. Depending on the specific application (e.g., indoor lighting, LCD, etc.) for which the post-processed composite 30 is to be used, the contributions of the blue, red and green components of the white light will be predetermined.

The blue spectral content of the light emission of the pre-processed composite 10 is provided by the nanocrystals and may be controlled by controlling the size of the nanocrystals. This is due to the fact that the blue-shift in the emission and absorption spectra of the nanocrystals increases as the particle size decreases due to quantum confinement. In the pre-processed composite material 10, the ZnSe nanocrystals 14 in the matrix material 12 are in a size range where quantum confinement of carriers (electrons and holes) may occur. Quantum confinement in this range will shift the energy levels of the ZnSe conduction band and valence band apart and hence give rise to a blue light contribution from the nanocrystals to the light emission. The blue spectral content of the light emission may also be controlled by controlling the number (or density) of the nanocrystals in addition to controlling the size of the nanocrystals.

The red and green spectral contents of the light emission of the pre-processed composite 10 may be controlled by controlling the number (or density) of red and green traps 16, 18. The traps 16, 18 are capable of trapping carriers and will decrease the efficiency and intensity of the blue light emission if the number of these traps are not reduced during processing to improve the blue light emitting efficiency and intensity of the pre-processed composite 10. These traps may take several forms that, in the case of ZnSe nanocrystals, may include certain selenium (Se) molecules (e.g., Se_2^-), selenium (Se) vacancies and zinc (Zn) vacancies. By reducing the number of these red and green traps 16 and 18, the amount of red and green spectral content of the light emission from the post-processed composite 30 may be reduced and the emission of the blue spectral content will be increased.

Figure 2 discloses the pre-processed composite 10 being irradiated and Figure 3A shows the effects after irradiation on the post-processed composite 30. The exact makeup of the pre-processed composite 10 with respect to nanocrystals and traps may vary before the processing disclosed herein. However, a consistent white light emission is desired from the post-processed composite 30 depending on a specific application. Indoor lighting, liquid crystal displays, and light emitting diodes are just some of the specific applications that the post-processed composite 30 may be used in and the white light emission of these specific applications will also vary.

Therefore, a first step in the method disclosed herein is to obtain a spectrum of the emitted light for the pre-processed composite 10 using an optical excitation source (e.g., laser, incandescent light). The spectrum of the emitted light is obtained nondestructively and without changing the properties of the pre-processed composite 10. An example of the spectrum of the emitted light of a pre-processed composite 10 is in Figure 1B. Reference numeral 40 indicates weak blue light emission from the pre-processed composite 10 due to the presence of a large number and density of traps 16, 18 which trap the carriers emitted from the nanocrystals 14 and reduce the blue emission. Reference numeral 42 indicates the spectrum of the emitted light from the large number and density of traps 16, 18 in the pre-processed composite 10. As may be observed in Figure 1B, emission in the red and green spectral range from the red and green traps 16, 18 dominates the overall light emission from the pre-processed composite due to the large number and density of the traps 16, 18.

In a second step, an analysis of the results of the spectral evaluation process discloses the amount of irradiation the pre-processed composite 10 will require to produce a white light emission for a specific application.

In a third step, the pre-processed composite 10 is irradiated for a predetermined amount of time. The irradiation may be performed using an optical energy source. Examples of suitable energy sources include lasers, incandescent lamps, arc lamps, electron beams, and other types of optical power sources. As discussed above, the power applied and the duration of the

irradiation step will be predetermined based on the specific application or end-use that the pre-processed composite 10 is being designed for and the results of the initial spectral evaluation step. The power used during the irradiation may range from approximately 10 milliWatts (mW) to 10 Watts. The duration of the irradiation may range from approximately 1 to 30 minutes.

Figure 2 illustrates, for exemplary purposes, an argon ion laser 20 irradiating on all lines 22 the pre-processed composite 10. In the example shown, to change from a pre-processed composite 10 to a white light emitting post-processed composite 30 as shown in Figure 3A requires irradiation having power of approximately 53 mW of power for approximately 2 minutes using all lines of an argon ion laser.

There are at least two factors or variables which determine the optimum power and time duration of the irradiation step to achieve the desired spectral makeup of the white light emission of the post-processed composite 30. First, the decrease in the size of the ZnSe nanocrystals and, second, the decrease in the number (or density) of red and green traps 16, 18. As shown in Figure 3A, the greater power used and the longer the pre-processed composite 10 is irradiated, the sizes of the ZnSe nanocrystals are decreased and, as a result, blue emission of the white light emission is increased. This result may be explained by the fact that the oscillator strength, which affects the intensity and efficiency of light emission, of quantum confined nanocrystals generally will have increased as the nanocrystal size decreases. Smaller nanocrystal sizes are

required to generate blue light. Therefore, as a result of the quantum confined nature of the blue light emission, a high efficiency for the blue component may be expected in the post-processed composite 30. Also, as shown by Figure 3A, the greater power used and the longer the pre-processed composite 10 is irradiated, the less red and green trap emission will result from the red and green traps 16, 18 because their number (or density) is reduced. The decrease in red and green trap emission not only produces less red and green spectral content to the white light emission from the post-processed composite 30, but also more blue emission is produced which previously is being trapped by the large number of red and green traps 16, 18. The red and green light may result from trapping of the excitation energy initially absorbed by the ZnSe nanocrystals that do not emit blue light. Therefore, most of the excitation energy given to the ZnSe nanocrystals will either be emitted as blue, green or red, and therefore, the overall efficiency of white light emission should be high. Defining the efficiency as the number of blue, green or red photons emitted by the composite divided by the number of excitation photons absorbed by the composite, the efficiency of the post-process composite 30 will be approximately in the range of 50 to 90% and, typically, greater than approximately 80%. The reduction in the red and green spectral composition of the white light emission and the increase in the blue component of the white light emission are shown by reference numeral 44 in Figure 3B.

After the irradiation step, another spectrum of the emission from the pre-processed composite is taken. If the spectral content does not meet the requirements of the specific application, multiple iterations may achieve the desired result. Figure 4 illustrates the iterative steps in flow diagram from. In step 410, the spectrum is taken. In step 412, a determination is made whether the spectrum is appropriate for the specific application. If the determination is positive, an efficient white light emitter composite has been created. If the determination is negative, in step 414, the pre-processed composite 10 is further irradiated. The number of iterations may typically range from approximately one to ten iterations depending on the specific application. However, it is to be understood that the number of iterations is not to be limited to ten. As previously discussed, the number of iterations will depend on the nature of the pre-processed composite and the specific application for which it is to be used.

In alternative embodiments, the blue light contribution to the white light emission may also be controlled by decreasing the number (or density) of the nanocrystals 14 in the matrix 12 in addition to decreasing their size.

In alternative embodiments, the nanocrystals 14 may also be selected from a group of similarly wide bandgap materials such as from Group II-VI, Group III-V, and Group IV semiconductor materials capable of emitting visible light upon excitation. Other examples of suitable nanocrystals may include CdSe and CdS.

In alternative embodiments the material used for the matrix 12 may be from a group that is of a transparently visible material suitable for having nanocrystals embedded within. Specifically, materials included in this group may include polymers (e.g., polystyrene), gels that have been solidified in a particular manner (e.g., sol-gels such as silica sol-gel), and materials having traps that emit light in the red and green spectral ranges.

In alternative embodiments the traps may be from a group of materials that emit visible light that may compliment the blue emission from the nanocrystals to give white light emission. Such trap materials may emit cyan and yellow light.

The resulting processed composite material may be used in a wide variety of applications including full color flat panel displays, scanners, facsimile machines, copy machines, optical data storage devices, internal lighting applications, light-emitting diodes (LEDs), automobile interior and exterior lighting, traffic safety lights, toys, and other general lighting purposes. In all these cases, an efficient and robust white light emitter is essential for high brightness, low weight and long operational life.

Figure 5 discloses a spectrally broad white light source for general lighting applications such as internal lighting for homes, automobiles, toys and exterior lighting. The power supply 52 provides the energy source to excite the post-processed composite 30 to give a white light emission. The power supply

52 may be from a stationary power supply source such as a conventional electrical socket or a mobile power supply such as a battery or batteries.

Figure 6 illustrates a liquid crystal display (LCD) 60 using the post-process composite material 30 as the white emitting back light. The power supply 52 provides an energy source to excite the post-processed composite material 30 in the LCD 60. The composite material 30 provides white light emission to a matrix addressable liquid crystal optical gate 64 and a picture element (pixel) display is produced. Figure 6 illustrates a monochrome liquid crystal display. For a full color liquid crystal display, three color filters (e.g., blue, red, and green) may be required for each pixel.

Figure 7 illustrates a light emitting diode (LED) 70 having various colors. The power supply 52 excites the post-processed composite 30 which emits white light. The white light emission is then transmitted through a color filter 72 (or color filters) which provides the color from the LED.

Figure 8 illustrates a pixel 80 of a full color electroluminescent display composed of a plurality of sub-pixels 83 each having a post-processed composite 30. Transmission of the white light from one of the post-processed composites 30 through red, green or blue filters 84 provides the color from an individual pixel 80. Power supply 52 is coupled to a controller 82 which specifies which composite 30 is energized and, therefore, specifies which color is emitted from the pixel 80. The controller 82 may be a matrix addressing circuit capable of distributing the energy from the power supply 52 to each sub-pixel 83.

An advantage of the exemplary embodiments disclosed herein is that the spectral makeup of the white light emission may be controlled by a simple and inexpensive irradiation process.

Another advantage of the exemplary embodiments is that the resulting processed composite will have shorter wavelength operation which is enabled by the blue-shifted quantum confined energy levels.

The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. The invention is defined by the following claims, with equivalents of the claims to be included therein.

CLAIMS

1. A method comprising:

directing an energy beam at a pre-processed composite material having a matrix containing a plurality of nanocrystals and a plurality of traps to reduce the size of said plurality of nanocrystals and the number of the plurality of traps to produce a post-processed composite material.

2. The method of claim 1, wherein said nanocrystals are from the group consisting of Group II-VI, Group III-V and Group IV semiconductor materials capable of emitting visible light upon excitation.

3. The method of claim 1, wherein said nanocrystals are ZnSe.

4. The method of claim 1, wherein said plurality of traps are from the group consisting of impurities that are capable of producing light emission upon excitation.

5. The method of claim 1, wherein said traps are from the group consisting of Se molecules, Se vacancies, or zinc vacancies.

6. The method of claim 1, wherein said matrix material is a transparent material that may contain said nanocrystals and traps that emit in the visible light range when fluoresced.

7. The method of claim 1, wherein said matrix material is a glass material.

8. The method of claim 1, wherein said matrix material is a potassium borosilicate material.

9. A method comprising:

directing an energy beam at a first state composite material having a plurality of nanocrystals and a plurality of traps to reduce the size of the nanocrystals and the number of said plurality of traps to produce a second state composite material capable of white light emission when fluoresced.

10. A method comprising:

fluorescing a pre-process composite material having a plurality of nanocrystals and a plurality of traps to obtain a light emission spectrum;

performing an analysis of said light emission spectrum;

directing an energy beam at the pre-process composite material to reduce the size of the plurality of nanocrystals and to reduce the number of the plurality of traps to produce a post-process composite material capable of white light emission when fluoresced.

11. A method of controlling the white light emission of a composite material comprising:

irradiating with an energy beam said composite material to reduce the size of a plurality of nanocrystals positioned in said composite material and to reduce the number of a plurality of traps positioned in said composite material.

12. A method of controlling the white light emission of a composite material comprising:

laser irradiating said composite material to reduce the size of a plurality of blue light emitting nanocrystals and to reduce the number of red and green light emitting traps.

13. A method comprising:

1) fluorescing a pre-process composite material having a plurality of nanocrystals and a plurality of traps to obtain a light emission spectrum;

2) performing an analysis of said light emission spectrum;

3) directing an energy beam at the pre-process composite material to reduce the size of the plurality of nanocrystals and to reduce the number of the plurality of traps to produce a post-process composite; and

4) repeating steps 1, 2 and 3 until a predetermined white light emission is obtained.

14. A material system produced by the method of claim 1.

15. A material system produced by the method of claim 10.

16. A material system comprising:

a plurality of nanocrystals;

a plurality of first and second traps; and

said plurality of nanocrystals, first traps and second traps capable of emitting white light in combination when excited.

17. The material system of claim 16, wherein said nanocrystals are from the group consisting of Group II-VI, Group III-V and Group IV semiconductor materials capable of emitting visible light upon excitation.

18. The material system of claim 16, wherein said nanocrystals are from the group consisting of ZnSe, CdSe, and CdS.

19. The material system of claim 16, wherein said first and second traps are from the group consisting of impurities that emit red and green light.

20. The material system of claim 16, wherein said first and second traps are from the group consisting of Se molecules, Se vacancies and zinc vacancies.

21. The material system of claim 16, further including a glass material.

22. The material system of claim 16, further including potassium borosilicate glass.

23. A material system comprising:

a plurality of nanocrystals designed to emit blue light when excited and having an average particle size of 1 to 20 nanometers;

a plurality of first traps designed to emit red light when excited; and

a plurality of second traps designed to emit green light when excited.

24. A material system comprising:

a matrix including nanocrystals having particle sizes in the range of 1 to 20 nanometers; and

said matrix further including first traps configured to emit red light and second traps configured to emit green light when fluoresced.

25. A material system capable of white light emission when excited comprising:

a matrix having a plurality of nanocrystals; and

said plurality of nanocrystals configured to contribute in the blue spectral range of the white light emission from the quantum confined bandedge emission of said nanocrystals when excited.

26. The material system of claim 25, further comprising:

a plurality of first and second traps; and

said first traps configured to contribute in the red spectral range of the white light and said second traps configured to contribute in the green spectral range of the white light when excited.

27. The material system of claim 26, wherein said plurality of nanocrystals have a predetermined size.

28. The material system of claim 27, wherein said plurality of first and second traps have a predetermined density to control the intensity of the white light emission when excited.

29. A method of tailoring white light emission from a composite having optical properties using ZnSe nanocrystals comprising:

fabricating said ZnSe nanocrystals;

incorporating said ZnSe nanocrystals into a matrix to form a composite; and

tuning the optical properties of said composite to a predetermined application.

30. The method of claim 29, wherein said optical properties include quantum confined bandedge emission from the ZnSe nanocrystals.

31. The method of claim 29, wherein said tuning of said optical properties is conducted by irradiating said composite.

32. The method of claim 29, wherein said tuning of said optical properties increases the efficiency of the spectral yield of said white light emission by optimizing the number density of the ZnSe nanocrystals.

33. The method of claim 29, wherein said tuning step controls contribution of a blue spectral region of the white light emission from quantum confined bandedge emission of the ZnSe nanocrystals.

34. The method of claim 29, wherein said tuning step controls contribution of blue, red and green portions of the white light emission by controlling the size of the ZnSe nanocrystals and the number of traps in the composite.

35. The method of claim 29, wherein said tuning of said optical properties is conducted by laser irradiating said composite to control amounts of red and green emission from a plurality of traps and to control blue bandedge emission from said ZnSe nanocrystals.

36. The method of claim 29, wherein said fabricating step further includes incorporating said ZnSe in an interface material located between matrix and said ZnSe nanocrystals; and

wherein said interface material is a transparently visible material.

37. The method of claim 36, wherein said interface material is glass.

38. The method of claim 37, wherein said glass material is potassium borosilicate.

39. The method of claim 29, wherein said fabricating step further includes incorporating said ZnSe in an interface material located between matrix and said ZnSe nanocrystals; and

wherein said interface material is a material capable of having nanocrystals embedded within.

40. The method of claim 29, wherein said fabricating step further includes incorporating said ZnSe in an interface material located between matrix and said ZnSe nanocrystals; and

wherein said interface material includes traps capable of emitting light in the red and green region of the spectrum.

41. The method of claim 29, wherein said fabricating step further includes incorporating said ZnSe in an interface material located between matrix and said ZnSe nanocrystals; and

wherein said interface material is a polymer.

42. The method of claim 29, wherein said polymer is polystyrene.

43. The method of claim 29, wherein said fabricating step further includes incorporating said ZnSe in an interface material located between matrix and said ZnSe nanocrystals; and

wherein said interface material is a sol-gel.

44. A material system produced by the method of claim 29.

45. A material system configured to produce white light emission when excited comprising:

a plurality of ZnSe nanocrystals in a predetermined size designed to optimize the contribution of blue light to the white light emission; and

a plurality of traps in a predetermined density designed to adjust the contribution of red and green light to the white light emission.

46. The material system of claim 16, wherein the efficiency of the white light emission is approximately in the range of 50 to 90%.

47. The material system of claim 16, wherein the efficiency of the white light emission is approximately greater than 80%.

48. A material system comprising:

a matrix having nanocrystals and capable of white light emission when fluoresced; and

wherein efficiency of said white light emission is approximately in the range of 50 to 90%.

49. A material system comprising:

a matrix having nanocrystals and capable of white light emission when fluoresced; and

wherein efficiency of said white light emission is approximately greater than 80%.

50. A white light source comprising:

a plurality of nanocrystals;

a plurality of first and second traps; and

said plurality of nanocrystals, first traps and second traps capable of emitting white light in combination when excited.

51. An LCD comprising:

a plurality of nanocrystals;

a plurality of first and second traps; and

said plurality of nanocrystals, first traps and second traps capable of emitting white light in combination when excited.

52. An LED comprising:

a plurality of nanocrystals;

a plurality of first and second traps; and

said plurality of nanocrystals, first traps and second traps capable of emitting white light in combination when excited.

53. An electroluminescent display comprising:

a plurality of composite material substrates each having

a plurality of nanocrystals;

a plurality of first and second traps; and

said plurality of nanocrystals, first traps and second traps capable of emitting white light in combination when excited.

ABSTRACT

A method of processing a composite material to tailor white light emission of the resulting composite during excitation. The composite material is irradiated with a predetermined power and for a predetermined time period to reduce the size of a plurality of nanocrystals and the number of a plurality of traps in the composite material. By this irradiation process, blue light contribution from the nanocrystals to the white light emission is intensified and red and green light contributions from the traps are decreased.

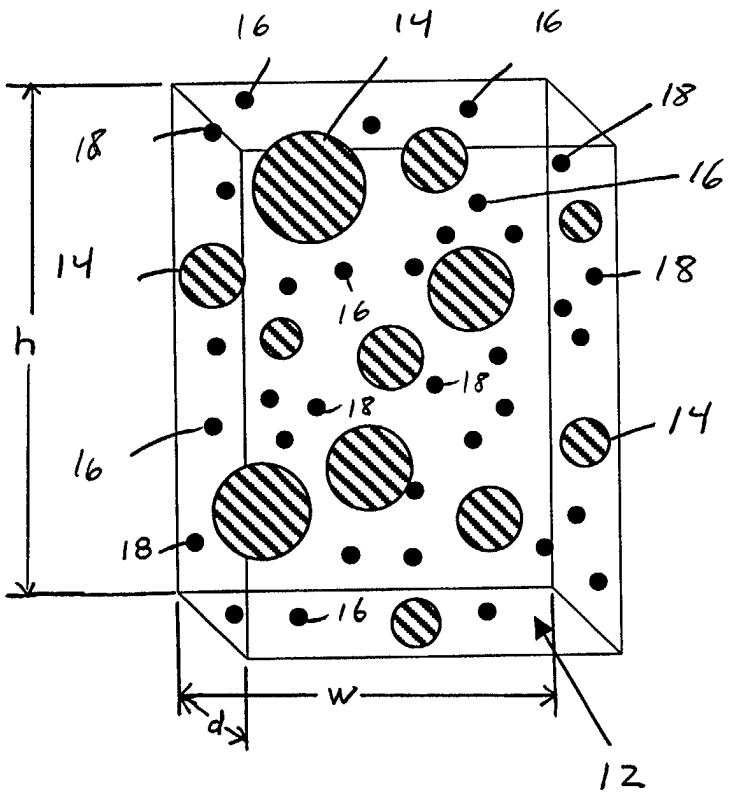


FIGURE 1A

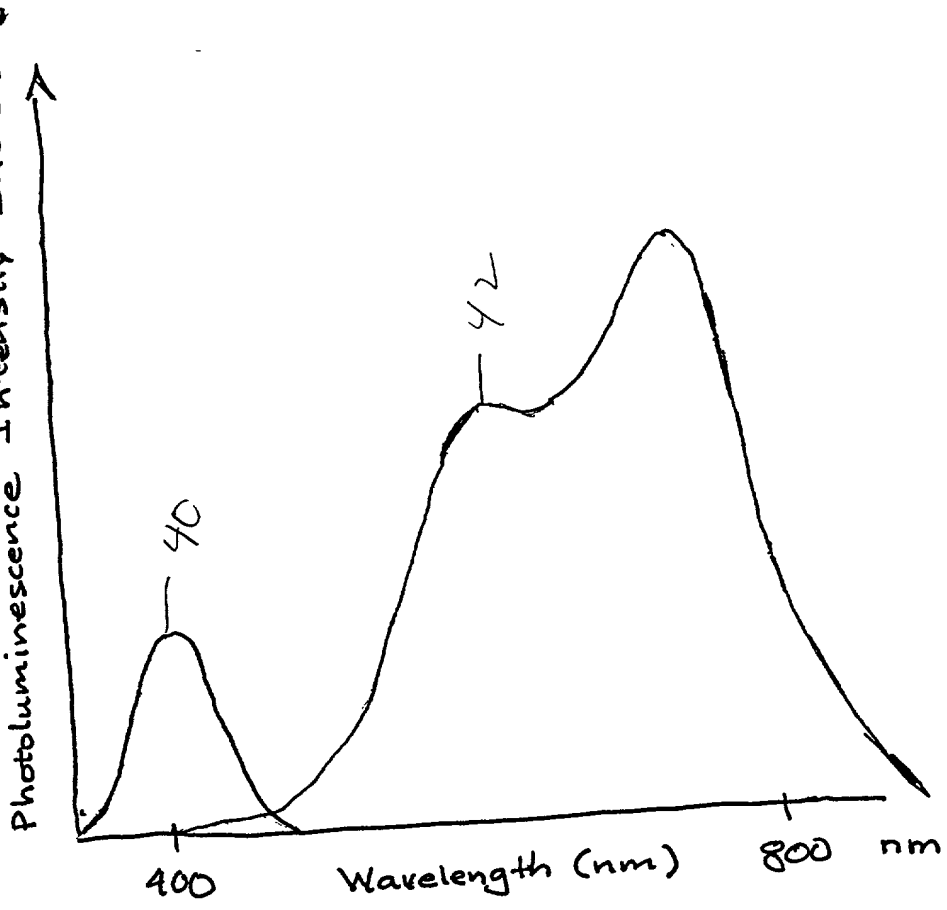

Photoluminescence Intensity Increasing
40
42
400
Wavelength (nm)
800
nm

FIGURE 1B

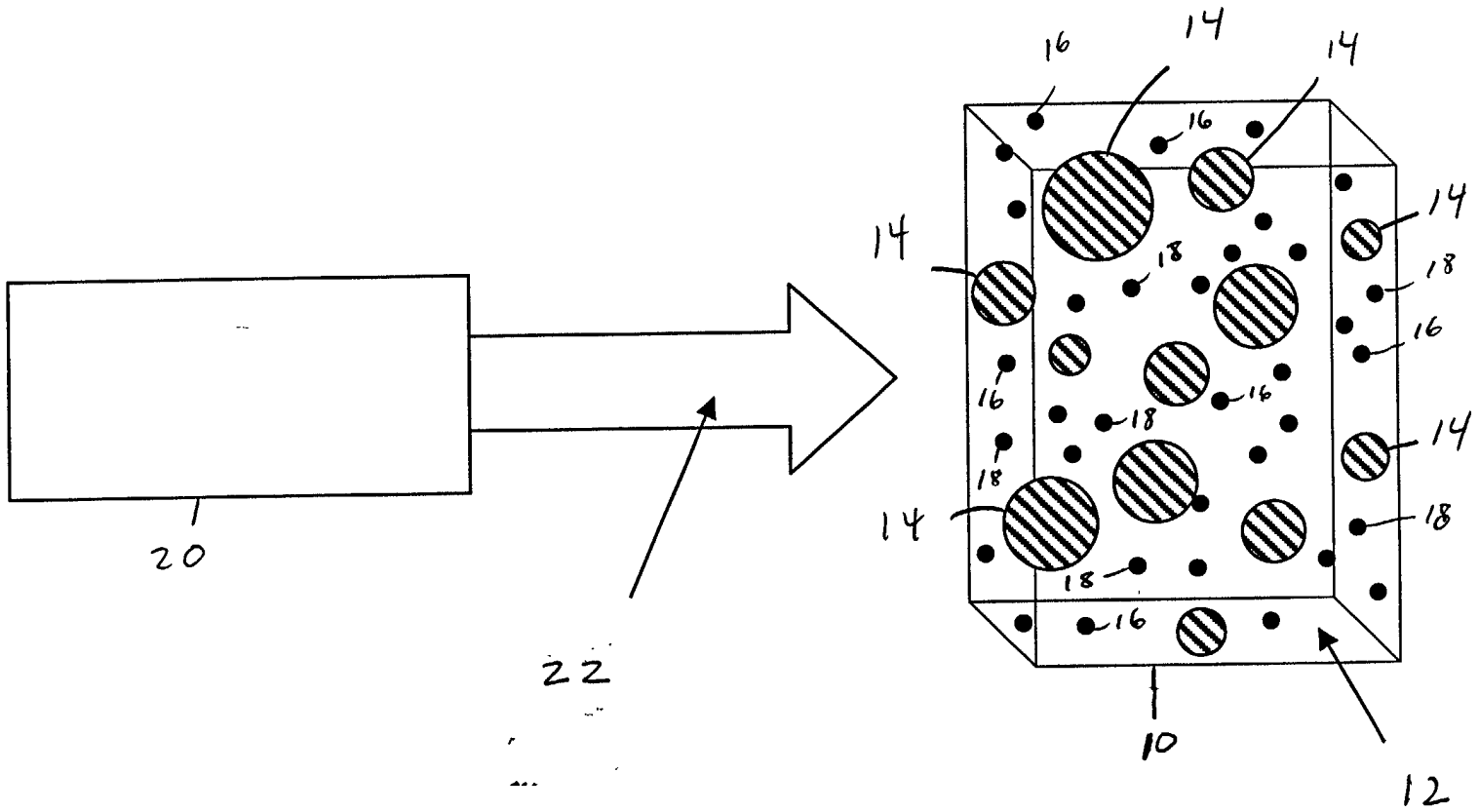
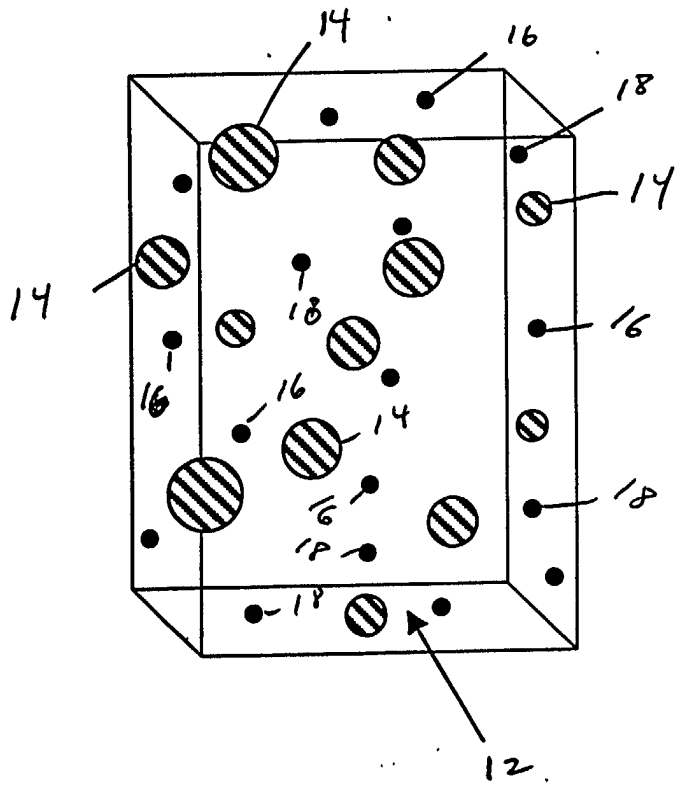


Figure 2



30

FIGURE 3A

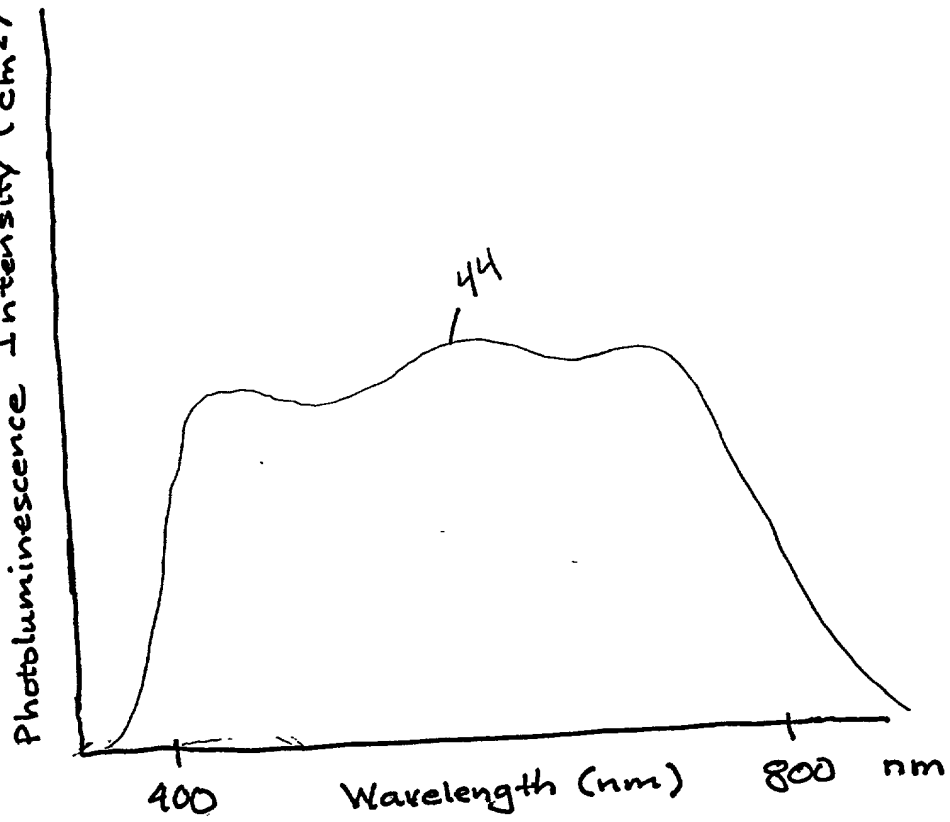

Photoluminescence Intensity ($\frac{W}{cm^2}$)
44
400
Wavelength (nm)
800
nm

FIGURE 3B

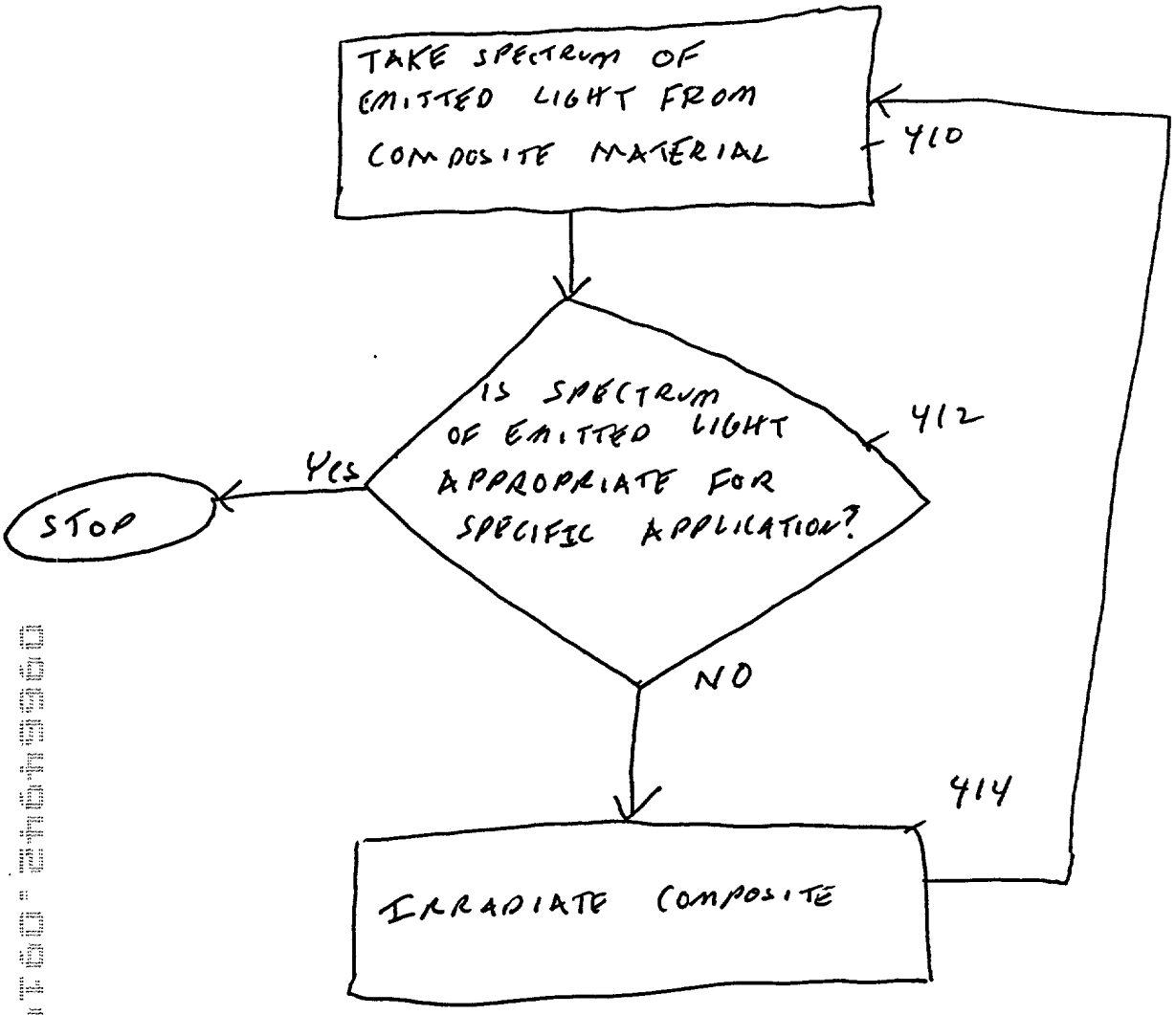

TAKE SPECTRUM OF EMITTED LIGHT FROM COMPOSITE MATERIAL
410
IS SPECTRUM OF EMITTED LIGHT APPROPRIATE FOR SPECIFIC APPLICATION?
412
YES
STOP
NO
IRRADIATE COMPOSITE
414

Figure 4

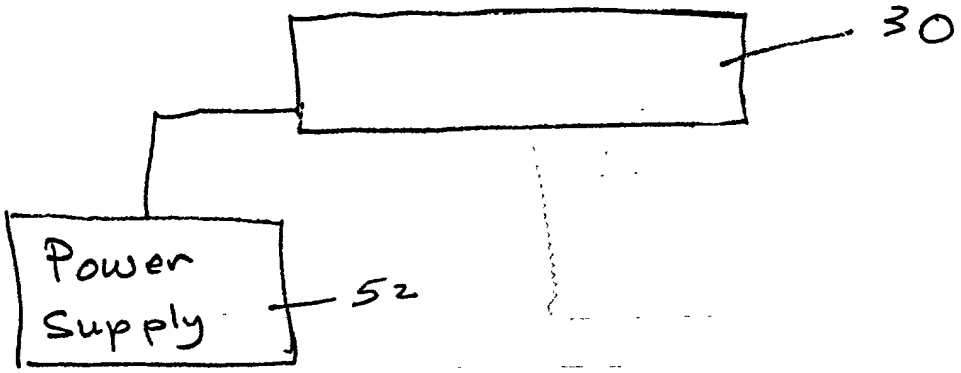


Figure 5

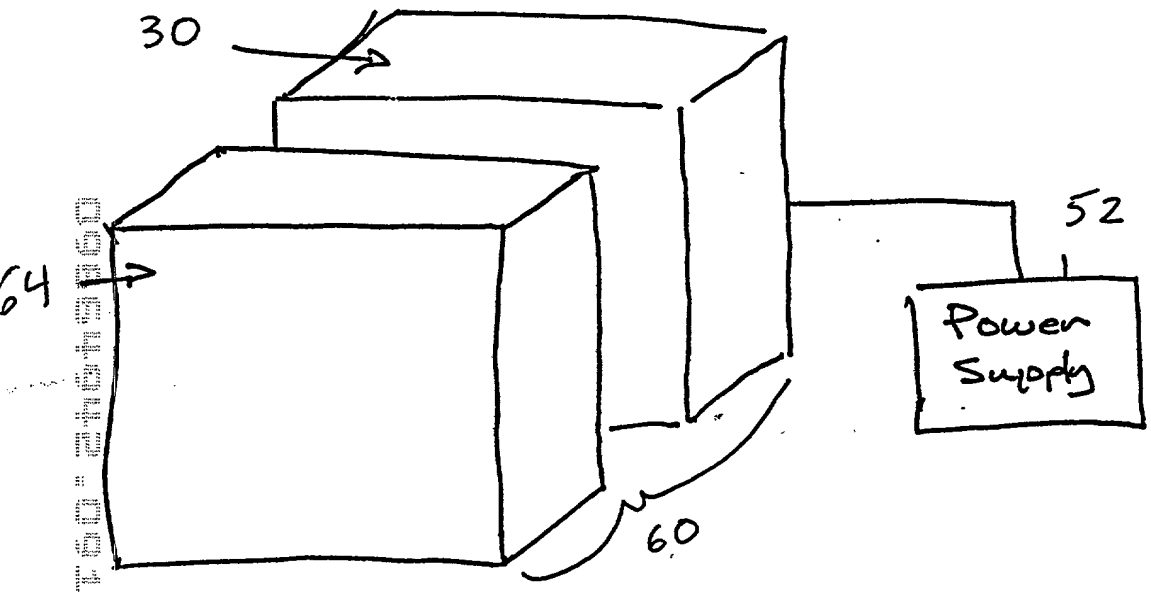


Figure 6

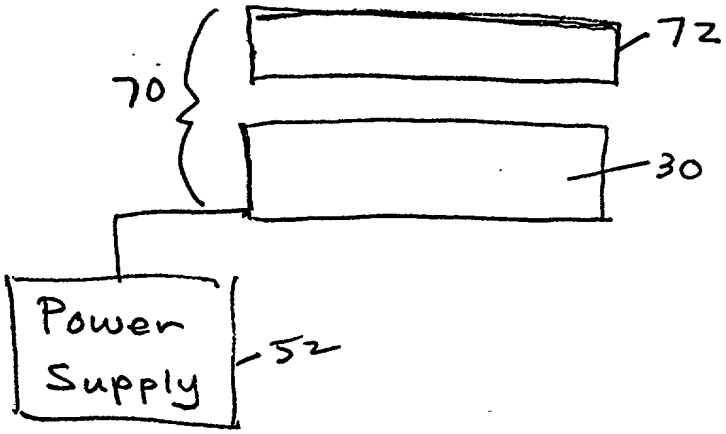


Figure 7

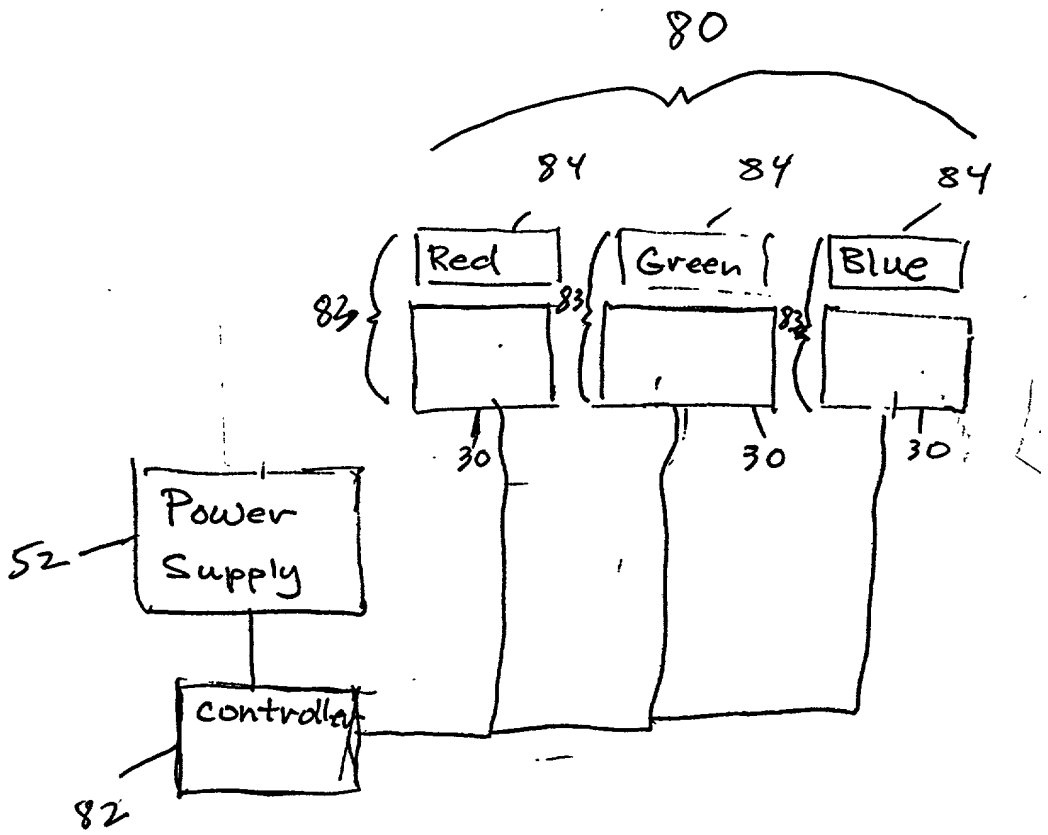

80
84
84
84
Red
Green
Blue
83
83
83
30
30
30
Power Supply
52
Controller
82

Figure 8

COMBINED DECLARATION AND POWER OF ATTORNEY

■ Declaration submitted with Initial Filing
❑ Declaration submitted after Initial Filing (surcharge (37 CFR 1.16(e)) required)

Attorney Docket: IL-10623
Applicant: Christine A. Smith et al.
Serial No.:
Filing Date:

As a below named inventor(s), I (we) hereby declare that:

My (Our) residence, post office address and citizenship(s) are as stated below next to my (our) name(s).

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: **MATERIAL SYSTEM FOR TAILORABLE WHITE LIGHT EMISSION AND METHOD FOR MAKING THEREOF**

the specification of which (check one)

____X____ is attached hereto _____was filed on_____ as United States Application Number or PCT International Application Number _____

and was amended on _____(if applicable).

I (We) hereby state that I (we) have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I (We) acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I (We) hereby claim foreign priority benefits under 35, U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)			Priority Not Claimed
(Application Number)	(Country)	(Foreign Filing Date)	❑
			❑

I (We) hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below:

Application Serial No.	Filing Date

I (We) hereby claim the benefit under 35 U.S.C. 120 of any United States applications(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

Application Serial No.	Filing Date	Status
NONE		

POWER OF ATTORNEY: As the named inventor(s), I (we) hereby appoint the following registered practitioner(s) to prosecute this application, and to transact all business connected therewith, in any patent office, U.S. or foreign.

Names:	Reg. No.	Name:	Reg. No.
Alan H. Thompson	29,981	Eddie E. Scott	25,220
L.E. Carnahan	20,555	James M. Skorich	27,594
Christopher J. Horgan	40,394		

Direct Correspondence To:	Direct Telephone Calls To:
Christopher J. Horgan Assistant Laboratory Counsel Lawrence Livermore National Laboratory P.O. Box 808, L-703 Livermore, California 94551	Christopher J. Horgan (925) 423-8554

DECLARATION

I (We) hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

First Inventor

CHRISTINE A. SMITH	Christine A. Smith
Full Name of Inventor	**Signature**
LIVERMORE, CALIFORNIA	**Date:** 9/13/00
Residence (City, State or Foreign Country)	
1264 BLOSSOM CIRCLE LIVERMORE, CALIFORNIA 94550	**USA**
Postal Address (Street, City, State, Zip Code)	Citizenship

Second Inventor

HOWARD W. H. LEE	Howard W. H. Lee
Full Name of Inventor	**Signature**
FREMONT, CALIFORNIA	**Date:** 9-13-00
Residence (City, State or Foreign Country)	
45176 IMNAHA COURT, FREMONT, CALIFORNIA 94539	**USA**
Postal Address (Street, City, State, Zip Code)	Citizenship

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